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Stability Analysis of a Flexible Vehicle Model Controlled by Human Pilot Models

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There is a constant race among automobile manufactures to design safer vehicles while minimizing weight to reduce power consumption. Additionally, organizations like NASA and SpaceX are persistently working toward creating reliable, lightweight rovers to be used on the surface of Mars. However, the lightweight requirement often increases vehicle flexibility, which further develops a tendency toward instability in the lateral (sideways) direction. This investigation develops a mathematical model that represents the dynamics of a flexible vehicle in forward motion, and a heuristic human pilot model is proposed which controls the vehicle. Following such formulation, the combined vehicle and pilot model is analyzed using 3 techniques: the Routh-Hurwitz stability criterion, direct eigenvalue analysis, and a time-marching simulation in MATLAB. Successive iterations are then made to the initial pilot model with the aim of better replication of human behavior, which are then each analyzed by the same set of stability methods. It is shown that the frame lateral stiffness (flexibility) of the vehicle plays a significant role in determining the lateral stability of the vehicle, provided that the vehicle has relatively stiff tires. These results are useful for designing highly flexible human-powered vehicles and rovers, but are also fundamental to safety mechanisms in automobiles.

KEYWORDS
Lateral stability, vehicle dynamics, human pilot model, stability analysis